Essentials of Geology, 11e

Geologic Time
Chapter 18

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Determining Geological Ages

- **Relative age dates** – placing rocks and events in their proper sequence of formation.
- **Numerical dates** – specifying the actual number of years that have passed since an event occurred (known as **absolute age dating**).

Principles of Relative Dating

- **Law of superposition**
  - Originally developed by Nicolaus Steno in 1669
  - In an *undeformed* sequence of sedimentary rocks (or layered igneous rocks), the oldest rocks are on the bottom.

Superposition

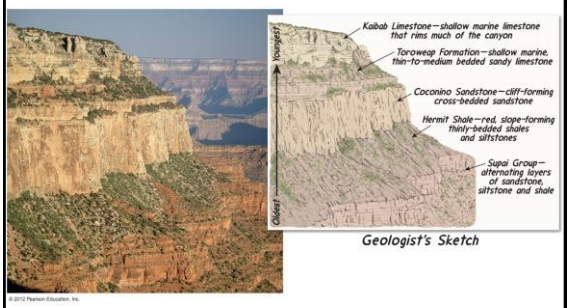


Figure 18.3

Principles of Relative Dating

- **Principle of original horizontality**
  - Layers of sediment are generally deposited in a horizontal position.
  - Rock layers that are flat have not been disturbed.
- **Principle of cross-cutting relationships**
  - Younger features cut across older features (faults, dikes, veins).

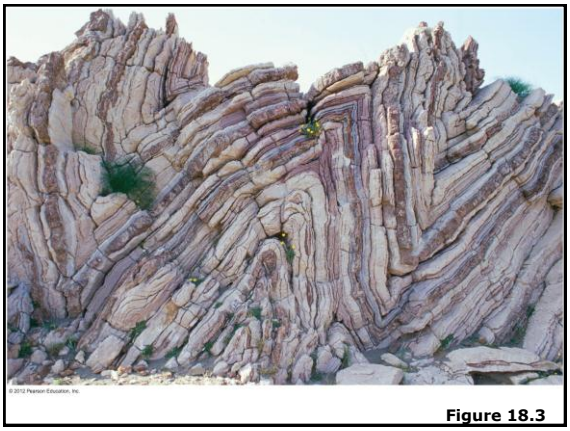


Figure 18.3

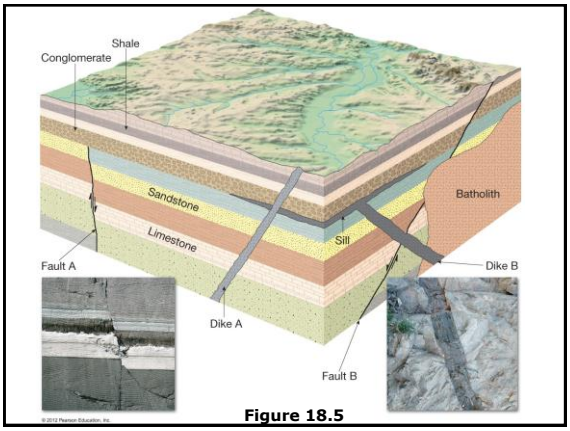


Figure 18.5

Principles of Relative Dating

- **Inclusions**
  - An inclusion is a piece of rock that is enclosed within another rock
  - Rock containing the inclusion is younger
- **Unconformity**
  - An unconformity is a break in the rock record produced by erosion and/or nondeposition of rock units

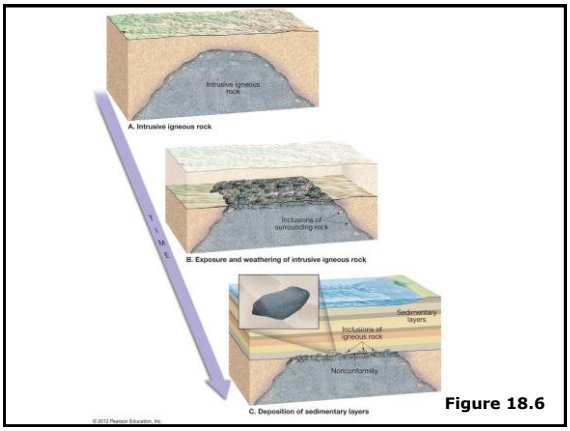


Figure 18.6

Principles of Relative Dating

- Unconformity
  - Types of unconformities
    - **Angular unconformity** – tilted rocks are overlain by flat-lying rocks
    - **Disconformity** – strata on either side of the unconformity are parallel
    - **Nonconformity** – metamorphic or igneous rocks in contact with sedimentary strata

Formation of an Angular Unconformity

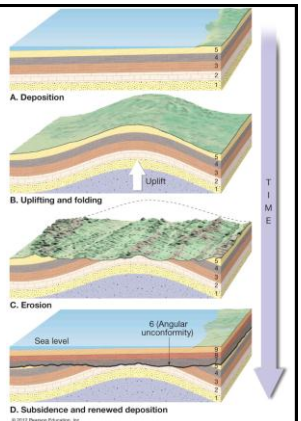


Figure 18.8

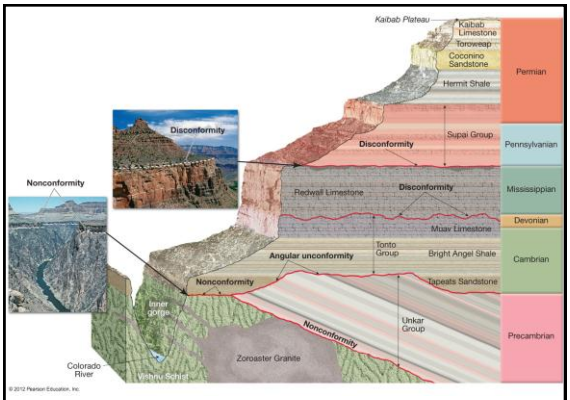
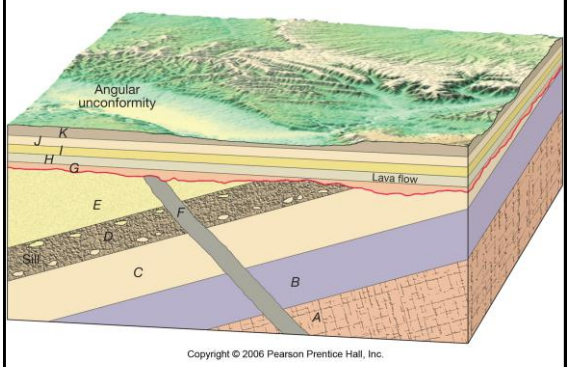


Figure 18.7

Figure 18.8



Fossils: Evidence of Past Life

- **Fossil** – the remains or traces of prehistoric life
- Important time indicators
- Correlate relative ages of rocks
- Types of fossils
  - The remains of relatively recent organisms – teeth, bones, etc.
  - Entire animals, flesh include
  - Given enough time, remains may be **petrified** (literally "turned into stone")

Fossils: Evidence of Past Life

- Types of fossils
  - Molds and casts
  - Carbonization
  - Others
    - Tracks
    - Burrows
    - Coprolites (fossil dung)
    - Gastroliths (polished stomach stones)

Fossils: Evidence of Past Life

- Conditions favoring preservation
  - Rapid burial
  - Possession of hard parts
- Fossils are more abundant in shales.
- Fossils are better preserved in low-energy environments.

Natural Cast and Mold of a Trilobite

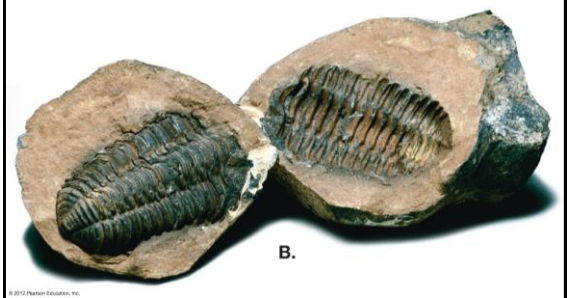


Figure 18.13 B

Fish Impressions

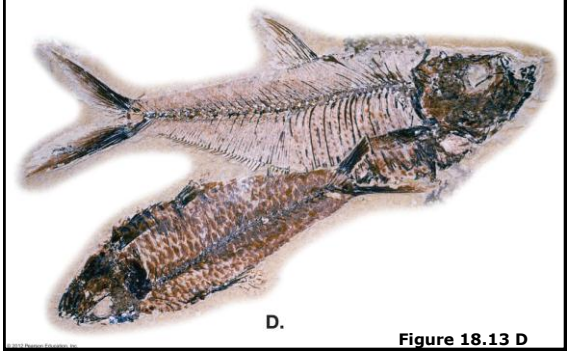


Figure 18.13 D

Coprolite

Fossil Hyena Dung

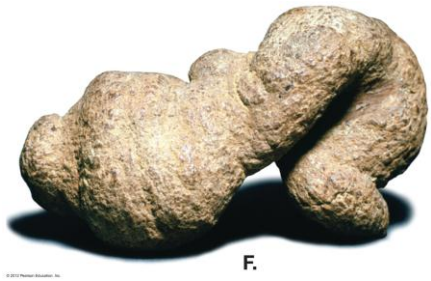


Figure 18.13 F

Fossils: Evidence of Past Life

- Correlation of rock layers
  - Matching of rocks of similar ages in different regions is known as ***correlation***
  - Correlation often relies upon fossils
    - William Smith (late1700s-early 1800s) noted that sedimentary strata in widely separated areas could be identified and correlated by their distinctive fossil content

Fossils: Evidence of Past Life

- Correlation of rock layers
  - Correlation often relies upon fossils
    - **Principle of fossil (faunal) succession** – fossil organisms succeed one another in a definite and determinable order, and therefore any time period can be recognized by its fossil content
  - **Index fossils**
    - Widespread geographically
    - Limited to short span of geologic time

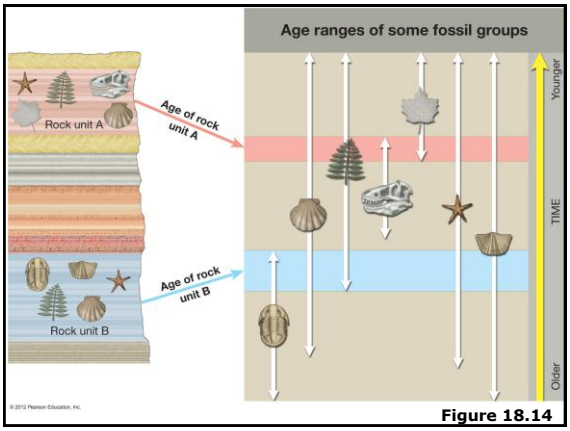


Figure 18.14

Using Radioactivity in Dating

- Reviewing basic atomic structure
  - **Nucleus** contains:
    - **Protons** – positively charged particles with mass
    - **Neutrons** – neutral particles with mass
  - **Electrons** – negatively charged particles that orbit the nucleus

Using Radioactivity in Dating

- Reviewing basic atomic structure
  - **Atomic number**
    - An element's identifying number
    - Equal to the number of protons in the atom's nucleus
  - **Mass number**
    - Sum of the number of protons and neutrons in an atom's nucleus

Using Radioactivity in Dating

- Reviewing basic atomic structure
  - **Isotope**
    - *Variant* of the same parent atom
    - Differs in the number of *neutrons*
    - Results in a different mass number than the parent atom

Using Radioactivity in Dating

- **Radioactivity**
  - Spontaneous changes (decay) in the structure of atomic nuclei
- Types of radioactive decay – 3 common
  - **Alpha emission**
    - Emission of 2 protons and 2 neutrons (an alpha particle)
    - Mass number is reduced by 4 and the atomic number is lowered by 2

Using Radioactivity in Dating

- Types of radioactive decay – 3 common
  - **Beta emission**
    - An electron (beta particle) is ejected from the nucleus
    - Mass number remains unchanged and the atomic number increases by 1
  - **Electron capture**
    - An electron is captured by the nucleus
    - The electron combines with a proton to form a neutron
    - Mass number remains unchanged and the atomic number decreases by 1

Types of Radioactive Decay

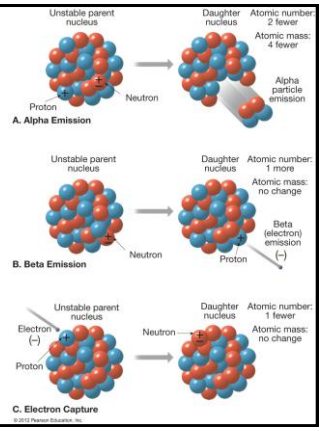


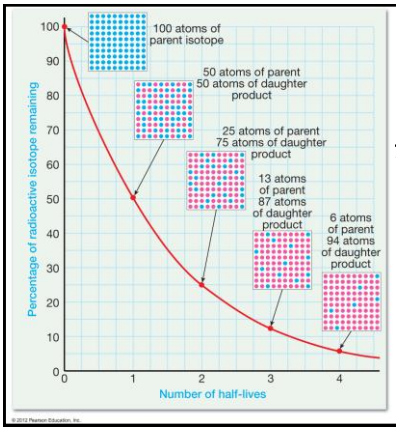
Figure 18.15

Using Radioactivity in Dating

- **Parent** – an unstable radioactive isotope
- **Daughter product** – the isotopes resulting from the decay of a parent
- **Half-life** – the time required for one-half of the radioactive nuclei in a sample to decay

Using Radioactivity in Dating

- **Radioactive parent Uranium-238**
  - Atomic # 92
  - Mass # 238
- **Decays by emitting 8 alpha particles and 6 beta particles**
- **Stable daughter product Lead-206**
  - Atomic # 82
  - Mass # 206



The Radioactive Decay Curve

Figure 18.17

Using Radioactivity in Dating

- **Radiometric dating**
  - **Principle of radioactive dating**
    - **The percentage of radioactive atoms that decay during one half-life is always the same (*50 percent*)**
    - **However, the actual number of atoms that decay continually decreases**
    - ***Comparing the ratio of parent to daughter yields the age of the sample***

Using Radioactivity in Dating

- **Radiometric dating**
  - **Useful radioactive isotopes for providing radiometric ages**
    - **Rubidium-87**
    - **Thorium-232**
    - **Two isotopes of uranium**
    - **Potassium-40**

TABLE 18.1

Radioactive Isotopes Frequently Used in Radiometric Dating

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years

Table 18.1

Using Radioactivity in Dating

- **Radiometric dating**
  - **Sources of *error***
    - **A closed system is required**
    - **To avoid potential problems, only fresh, unweathered rock samples should be used**
    - **Minerals may weather or recrystallize.**

Using Radioactivity in Dating

- Dating with carbon-14 (radiocarbon dating):
  - Half-life of only 5730 years
  - Used to date very recent events
  - Carbon-14 is produced in the upper atmosphere from nitrogen-14
  - Useful tool for anthropologists, archeologists, and geologists who study very recent Earth history

Using Radioactivity in Dating

- Importance of radiometric dating
  - Radiometric dating is a complex procedure that requires precise measurement
  - Rocks from several localities have been dated at more than 3 billion years
  - Confirms the idea that geologic time is immense

Geologic Time Scale

- The *geologic time scale* – a "calendar" of Earth history
  - Subdivides geologic history into units
  - Originally created using relative dates
- Numerical dates were added long after the time scale had first been established using relative dating techniques.

Geologic Time Scale

- Structure of the geologic time scale
  - Eon – the greatest expanse of time
  - Names of the eons
    - Phanerozoic ("visible life") – the most recent eon, began about 542 million years ago
    - Precambrian (~4.6 – 542 mya)
      - Proterozoic
      - Archean
      - Hadean – the oldest eon

Geologic Time Scale

- Structure of the geologic time scale
  - Era – subdivision of an eon
    - Eras of the Phanerozoic eon
      - Cenozoic ("recent life")
      - Mesozoic ("middle life")
      - Paleozoic ("ancient life")
    - Eras are subdivided into periods
    - Periods are subdivided into epochs

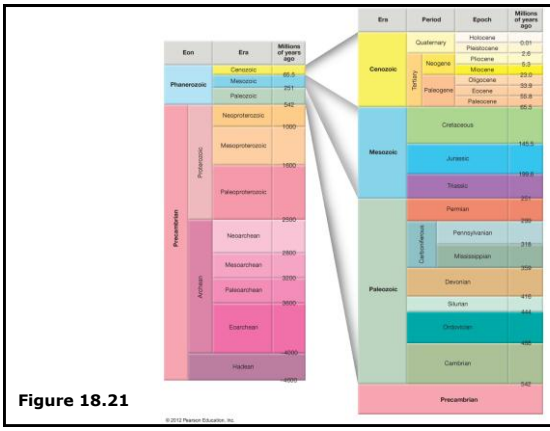


Figure 18.21

Geologic Time Scale

- **Precambrian time**
  - **Nearly 4 billion years prior to the Cambrian period**
  - **Not divided into smaller time units because the events of Precambrian history are not known in enough detail**
    - **First abundant fossil evidence does not appear until the beginning of the Cambrian**

Geologic Time Scale

- **Difficulties in dating the geologic time scale using dating methods:**
  - **Not all rocks can be dated by radiometric methods**
    - ***Grains* comprising detrital sedimentary rocks are not the same age as the rock in which they formed.**
    - **The age of a particular mineral in a *metamorphic* rock may not necessarily represent the time when the rock formed.**

Geologic Time Scale

- **Difficulties in dating the geologic time scale using dating methods:**
  - **Datable materials (such as volcanic *ash* beds and igneous intrusions) are often used to bracket various episodes in Earth history and arrive at ages.**

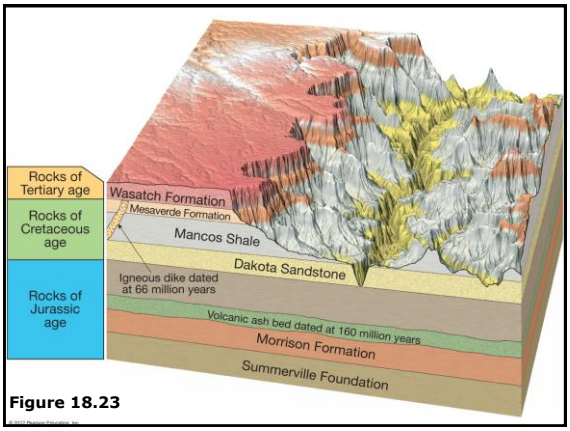
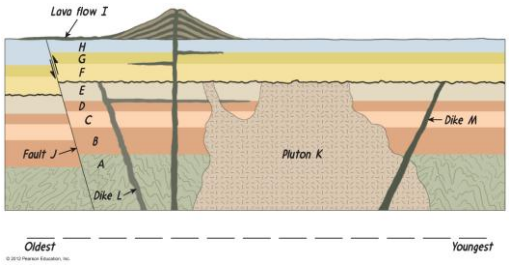


Figure 18.23

Relative Age Dating



End of Chapter 18